Remote Automatic Control of DSS 13

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The control of pulsar observing at the Venus station (DSS 13) by an operator at JPL is described. The emphasis is on the JPL end of the system and the communication between JPL and DSS 13. A six-hour observing run on August 14, 1975, is described.

I. Introduction

The remote automatic pulsar data acquisition system at DSS 13 is now operational. Once the station is put into a specified initial configuration, no further action is required of the station personnel until the end of the observing run. The pulsar observing is controlled by an operator located at JPL. Status messages and data are sent to JPL. On August 14, 1975, the system was used for a six-hour observing run. This system is an extension of the locally controlled automatic system described in Ref. 1.

Section II describes the DSS 13 end of the system and Section III the JPL end. In Section IV the communication between DSS 13 and JPL is described. In Section V the details of the observing run on August 14, 1975, are presented, and in Section VI plans for future use and development of the system are given.

II. DSS 13

Three SDS computers at DSS 13 are involved in the control. The 16-kiloword memory SDS 930 is the station control computer. It generates commands for the other two computers, initiates collection of pulsar data, plots and records the data, and communicates with JPL. The 8-kiloword SDS 910A controls a programmable oscillator; the 8-kiloword SDS 910B controls the 26-meter antenna. Each of the 910's is connected to the 930 by a twin coaxial cable communication link.

The 930 is programmed in real-time FORTRAN; the 910's are programmed in assembly language. All of the programs are interrupt driven. That is, most actions are done in response to externally generated interrupts rather than in a specified sequential manner.

The station configuration is the same as that for the locally controlled automatic pulsar data acquisition system except that there are two additional interrupts into the 930, associated with the JPL communication.

III. JPL

Two computers at JPL are involved in the control. The 8-kiloword memory SDS 920 acts as a communications buffer; the 32-kiloword XDS Sigma 5 is the control computer. The Sigma is a time-shared computer with the ability to have programs run simultaneously from the batch entry (card reader) and from a remote terminal. The pulsar data acquisition system is controlled through the terminal. The Sigma program is written in FORTRAN. Features in the Sigma FORTRAN allowed the Sigma program to be written as a structured program.

The Sigma program was written so that incoming status information and data would be handled automatically without JPL operator intervention. Therefore, status messages are displayed on the terminal when received, and are also stored on the random-access device (RAD) for later retrieval. A message is displayed when a data block is received, and the data and parameters for the observation are stored on the RAD. At any time the operator may request the display of the status messages or observation parameters received during a specific time period or he may request that one or more data blocks be plotted. The plotter uses only single sheets of paper, so continuous plotting is not practical.

The only output devices accessible to terminal programs are the terminal cathode-ray tube (CRT) display, the plotter and the RAD. During an observing run, there is no way to get hard-copy output at the Sigma computer. Once the observing run is finished, the contents of the files stored on the RAD can be recorded on magnetic tape or listed on the printer using programs from the batch entry.

Sending commands to DSS 13 is done at the request of the operator. Once observing on a pulsar has been started, observations will continue to be taken until commanded otherwise. As with the locally controlled automatic system, the remote controlled system is controlled by Tutorial Input. The command entry is from the Sigma terminal keyboard, and the responses and error indications are displayed on the terminal. The Tutorial Input communication is also typed out on the 930 typewriter at DSS 13. The message "DONE" is displayed on the terminal each time a complete set of commands has been received by the 930. By waiting for this message, the JPL operator insures that the 930 program is not hung up in the Tutorial Input routine because of insufficient parameters or an error in the input. The Tutorial Input commands are the same as those used for the locally controlled system and are given in Appendix A.

The Sigma program is also controlled by Tutorial Input. The commands and parameters are listed in Appendix B. There is no overlap in names between the Sigma Tutorial Input commands and the 930 Tutorial Input commands, so an "UNRECOGNIZED COMMAND" message will be given if a command is entered for the wrong mode.

IV. Communication Between DSS 13 and JPL

Communication between DSS 13 and JPL is conducted by means of dedicated teletype lines between the SDS 930 at DSS 13 and the SDS 920 at JPL. The 920 is connected to the Sigma 5 by a twin coaxial cable communication link.

The development of the software handling the communication between the 930 and the Sigma through the 920 was separated from the development of the rest of the software. An interface between the non-communication or background software and the communication software was specified in the form of a set of FORTRAN subroutine calls along with the function of each of the subroutines. The implementation of these subroutines in both the Sigma and the 930 and the 920 program will be described separately.

As far as the background programs are concerned, the Sigma communicates directly with the 930. The communication is divided into two logical channels. The background programs can treat them as two physically separate, full-duplex (allowing simultaneous communication in both directions) channels. There is actually only a single physical channel which, at least for the 920–Sigma link, is half-duplex (one direction at a time). The communication software takes care of merging and separating the messages.

The Tutorial Input communication is carried in both directions on one channel; the status messages and data are carried from the 930 to the Sigma on the other

channel. The status messages are listed in Appendix C. The OBSR message alerts the Sigma program that the next message is a data block. Because the transmission rate of the teletype lines is very low (ten 5-bit characters per second), the data block contains 250 averaged points rather than the 5000 original data points. This is sufficient to determine the quality of the data.

V. Details of Observing Run

On August 14, 1975, the remote automatic pulsar data acquisition system was used for a six-hour observing run. Seven different pulsars were observed. The observing schedule was supplied by one of the scientists of the pulsar observing project. The station personnel were not notified by phone in advance of changes in the antenna position, although they could look at the Tutorial Input typeouts. Much of the time the JPL end was left unattended. The Sigma was used by others in batch mode during the observing run. The observations are tabulated in Table 1.

VI. Future Developments

One major change in the system will be the addition of scheduling. This will allow the JPL operator to enter the entire observing schedule at one time. He will later be able to change the schedule, based on the results of the observing. If he wished, he could leave the system unattended.

Some other changes are being considered. One is the use of high-speed data lines instead of the teletype lines so that the primary data record will be at JPL rather than at DSS 13. Another is the inclusion of sufficient controls and monitors for the station to be left unattended. This will necessitate including a wind monitor so the system will stow the antenna in case of high wind.

It is intended that the system be used on a regular basis to collect pulsar data and to study its reliability. Additional status tests and messages may be added to increase the failure detection, and some failure isolation and correction may be included.

Reference

1. Moyd, K. I., "Automatic Control of DSS 13," in *The Deep Space Network Progress Report 42-29*, pp. 107–114, Jet Propulsion Laboratory, Pasadena, Calif., Oct. 15, 1975.

Table 1. Pulsar observations on August 14, 1975

ID number	Start time, UT	Number of observations[a]
0329	16 14 10	4
0355	16 43 14	15
0833	17 38 23	15
0525	18 27 29	3
0823	20 05 03	13
1133	21 17 21	4
1642	22 02 22	3

[a]The time per observation depends on the pulsar period and ranges from 3 minutes for 0833 to about 30 minutes for 0525.

Appendix A
930 Tutorial Input Commands

I. Basic Parameter Entry

Command	*Parameter*	*Description*
OFFD		Change default offsets. New values will be used immediately.
	AZDF	Default azimuth offset in degrees. Initially: .145.
	ELDF	Default elevation offset in degrees. Initially: 0.
DIST		Change pointing parameters. The new values will not be used until a new antenna command is given. Values are to be entered in millidegrees (i.e., 10 degrees is entered as 10000).
	HSPD	Minimum azimuth pointing error for which high speed is to be used. Elevation value is half of azimuth value. Initially: 12000.
	DECL	Azimuth pointing error at which high-speed deceleration is started. Elevation value is half of azimuth value. Initially: 10000. (It is required that DECL < HSPD.)
	TRKD	Maximum pointing error (in each axis separately) for on-target condition to be satisfied. Initially: 50.
	TRKV	Maximum velocity (in each axis separately) for on-target condition to be satisfied. Initially: 25.
PDCL		Change default pulsar data collector parameters. The new values will be used the next time parameters are sent to the data collector (i.e., following an OBJ, GO, TSYN, ENDO or EXP command).
	XDEF	Number of synthesizer pulses between observations. Initially: 200.
	YDEF	Number of observations per period. Initially: 5000.
DATE		Enter date. (Date is based on UT, not local time.)
	MON	Month—up to 4 numbers or letters.
	DAY	Day of the month.
	YEAR	Year—4 digits.

II. Antenna Commands

A. New Position

These are acted upon immediately if the previous antenna command was STOP, AZEL, or STOW; if the antenna was stopped by the computer for another reason (breakpoint 4 set and then reset, elevation too low); or when the program is first started. Otherwise they will be acted on after the current observation is finished and the data processed.

Command	*Parameter*	*Description*
AZEL		Move the antenna to the specified azimuth and elevation and hold it there.. Do not collect data.
	AZ	Azimuth between 0 and 360 degrees with up to three decimal places. The decimal point must be typed.
	EL	Elevation in degrees with up to three decimal places. The decimal point must be typed.
	REGN	Wrap-up region. 'R' for right, 'L' for left. Anything else will be interpreted as center.

Command	*Parameter*	*Description*
STOW		Move the antenna to the stow position (AZ = 180 degrees, EL = 85 degrees, center region) and hold it there.
OBJ		Move the antenna to the specified right ascension (RA) and declination (DEC) and track. When the antenna is on-target, initiate data collection with a start-next-second.
	ID	Pulsar identification number—up to 4 digits.
	RA	Hours of RA.
	RAM	Minutes of RA.
	RAS	Tenths of seconds of RA (i.e., 34.5 seconds is put in as 345).
	DEC	Degrees of DEC. Include sign if negative.
	DECM	Minutes of DEC, no sign.
	DECS	Seconds of DEC (2 digits), no sign.
	TMCN	Time constant setting for the pulsar receiver.

B. Other Control Commands

STOP	Stop the antenna (decelerate safely, put on the brakes, change to low speed). Ignore any data being taken. Acted upon immediately. To resume operation, one of the other antenna commands must be given.
GO	Resume observation of the object entered by the previous OBJ command. Used after the antenna has been stopped. Acted upon immediately unless breakpoint 4 is set.

III. Data Collection Commands

All of the commands except ENDO are acted upon only after the data from the current observation has been processed.

Command	*Parameter*	*Description*
LINK		Enable the 930–910A link.
NLNK		Disable the 930–910A link. (This is the initial condition).
PLO		Entry of oscillator frequency. If the 930–910A link is enabled, the frequency will be sent to the local oscillator and the setting will be confirmed. The next observation will be a start-next-second.
	FREQ	Oscillator frequency in hertz. Up to 10 characters including the decimal point.
WAIT		Do not start the next observation until another command has been received. This allows the operator to see the data before specifying a new observation.
CONT		Initiate a start-in-phase-add after a WAIT command has been given.
TSYN		Initiate a start-next-second. (This is done automatically for the first observation after an OBJ. GO, PLO or ENDO command.)

Command	*Parameter*	*Description*
ENDO		Abort the current observation and ignore the data. It is acted upon immediately if an observation is in progress. Otherwise it has no effect. If no other command is received, the next observation will be a start-next-second.
EXP		Subsequent observations are to be expanded. The parameters are based on the data taken as the result of the previous start-next-second command. These expansion parameters will be used until an antenna command, PLO, TSYN, ENDO or another EXP command is given.
	DEL	The original data point (between 0 and YDEF-1) corresponding to the 0th observation (i.e., origin) for the expanded observations. If DEL = 0, the origin is in phase with the second at which the original observation was taken.
	IINT	The number of *original* data points to be included in the expanded observations.
	IEXP	The expansion factor (number of observation points for each original observation). IEXP must be a factor of XDEF. IEXP $\times$ IINT $\leq$ 5000.

Appendix B
Sigma Tutorial Input Commands

Command	*Parameter*	*Description*
STAT		Display status messages or data parameters.
	UTB	UT of earliest message to be displayed.
	UTE	UT of latest message to be displayed.
	TYPE	"STAT" for status messages. "PULS" for data parameters.
PLOT		Plot one or more data records.
	REC B	Record number of first record to be plotted (obtained from DATA message or data parameter display).
	NREC	Number of records to be plotted.
GTS		Send commands to DSS 13. All subsequent keyboard entries will be sent to DSS 13 until "ENDT" is typed.

Appendix C
Status Messages

I. Introduction

Status messages may indicate normal operation or they may indicate error conditions. Normal operation messages are used to keep the remote operator aware of the progress of the observing and to notify him when a new data block has been received. The error messages are in response to failures occurring in the antenna system, the teletype link, the program timing, and the local oscillator setting. In general, they do not require any response from the remote operator to protect the system; however, response may be necessary to resume operation. Certain of the messages may occur in response to a command given by the operator. For example, an ENDO command will generate a STOP OBS message; a STOP command will generate a STOP ANT message. These will be listed as error messages since they will not be expected to occur under normal operating conditions. Some messages are generated within the Sigma 5 rather than being received from DSS 13. These will not be stored on the disk for later retrieval and will not be displayed if they occur during plotting. This fact will be noted in the message description.

II. Normal Operation Messages

Message	*Type*	*Description*
ON	TARG	Antenna is on-target, i.e., the position error in each axis is less than TRKD (see Tutorial Input commands) and the velocity error in each axis (based on the source tracking velocity) is less than TRKV. An observation has been started.
OBSR		An observation has been completed and data are being sent. The parameter is the pulsar ID number.
	1	Observation was a start-next-second.
	2	Observation was a start-in-phase-add.
	3	Observation was a start-in-phase-clear.
DATA		Data have been received and can be plotted. The parameter is the pulsar ID number. The record number is that corresponding to the data record. This message is not stored on the disk. The STAT command can be used to retrieve the complete observation message later.

III. Error Messages

Message	*Type*	*Description*
FRER		The local oscillator setting does not agree with that commanded. The command to the local oscillator will be repeated. No parameter.
ANTE		The antenna cannot be controlled by the computer. The parameter gives the specific reason: 1 Hydraulic pressure too low. 2 Antenna in azimuth prelimit zone. 4 Antenna in elevation prelimit zone. 8 Computer not given control. The parameter is the sum of all the applicable codes; e.g., a parameter of 9 indicates hydraulics off and manual control. This message is repeated once a minute as long as one of the conditions applies.

Message	*Type*	*Description*
ATO1		A command to change one of the antenna functions has not been obeyed. This message occurs one minute after the command was given.
	AZBR	The command was for azimuth brakes. The parameter $= -1$ for commanded set; 1 for commanded release.
	ELBR	The command was for elevation brakes. The parameter $= -1$ for commanded set; 1 for commanded release.
	AZSP	The command was for azimuth speed. The parameter $= -1$ for commanded low speed; 1 for commanded high speed.
	ELSP	The command was for elevation speed. The parameter $= -1$ for commanded low speed; 1 for commanded high speed.
ATO2		A command to change one of the antenna functions has not been obeyed. This message occurs two minutes after the command was given (one minute after the corresponding ATO1). No further messages are sent. The types and parameters are the same as for ATO1.
POSN	EL	The elevation is out of range. This message is always given if the source has elevation < 0 degrees. If the source has elevation between 0 and 8 degrees, the message is given if the source is setting (elevation decreasing). The antenna will be stopped until a new antenna command is given.
PP50		There were not fifty 50-pulse-per-second interrupts during one second. The parameter specifies how many did occur. This condition may occur while data are being written on the magnetic tape; it will not affect tracking or data collection in this case.
STOP	ANT	The antenna has been stopped by the computer in response to a STOP command from JPL or the setting of breakpoint 4 at DSS 13. In the latter case, the antenna cannot be moved until breakpoint 4 is reset. In either case, it will not be moved until an antenna command is given.
	OBS	The current observation has been aborted by an ENDO command. Unless an antenna or data collection command has been given, a start-next-second observation has been initiated.
TTY		An unrecovered error has occurred on the link between JPL and DSS 13.
	SEND	The error was in sending from DSS 13 to JPL. The parameter gives the channel: 1 Data and message channel. 2 Tutorial Input channel.
	REC	The error was in sending from JPL to DSS 13 on the Tutorial Input channel. The parameter gives the number of attempts. After the second attempt, the Tutorial Input will be terminated under the assumption that the link is down. (The 930 may be hung up waiting for the input.) This message is not stored on the disk.